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A GRAPHICAL METHOD FOR DETERMINING TOWLINE TRAIL AND THE SHAPE --ETC(U)
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A GRAPHICAL METHOD FOR DETERMINING TOWLINE TRAIL AND THE SHAPE OF A TOWLINE CURVE.

by

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INTRODUCTION

In VDS applications, it is desirable to know the shape of the towline curve in order to determine the position of the towed body relative to the towing vessel. If kiting is nonexistent, the towline can be assumed to lie in a vertical plane and its shape can be described in an X and Y coordinate system. The Y-axis would represent depth and the X-axis would represent trail, the distance directly astern of the towing vessel. This memorandum describes a technique for determining the values of X, trail, and the shape of the towline curve.

Any plane curve, when referenced to a fixed two-dimensional coordinate system in the plane of that curve, can be described fully by determining the coordinates for each of the infinite number of points on the curve. If the coordinates of these points are known the curve can be graphically constructed, and the length between any two points along the curve can then be determined. If the curve reflects a mathematical relationship where one coordinate can be expressed mathematically as a function of the other, the length, S, between any two points can be found mathematically,

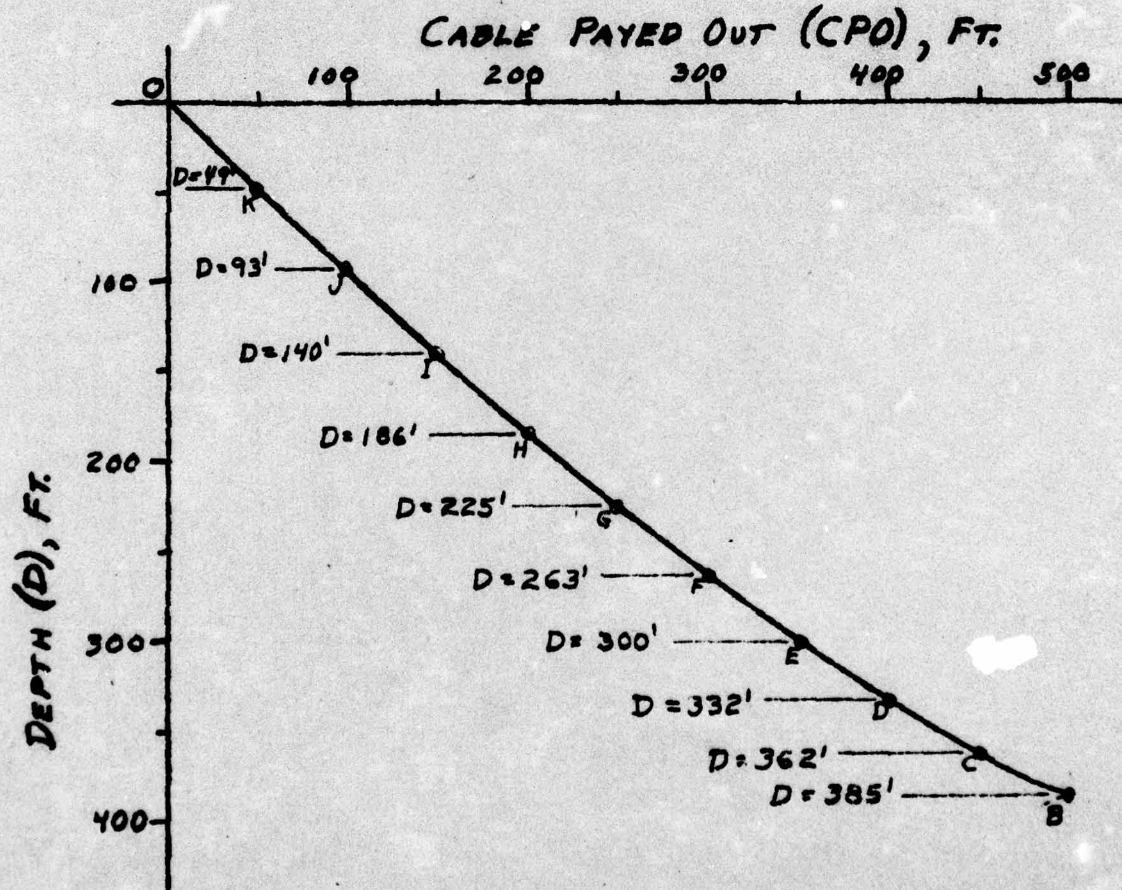
$$\int_{S_1}^{S_2} ds = \int_{x_1}^{x_2} \sqrt{1+\left(\frac{dy}{dx}\right)^2}\, dx$$

The length, S, can be measured graphically if the curve reflects empirical data. The curve can also be described fully by specifying

S as a function of one or both coordinates, either mathematically or emphirically. The depth at the bottom of the towline can be determined within the accuracy limitations of the measurement; however, the distance astern (trail) is not easily measured. The amount of cable payed out, S, can be measured accurately; therefore, S can be specified empirically as a function of depth and values of X can be graphically determined.

GRAPHICAL PROCEDURE

The figure below



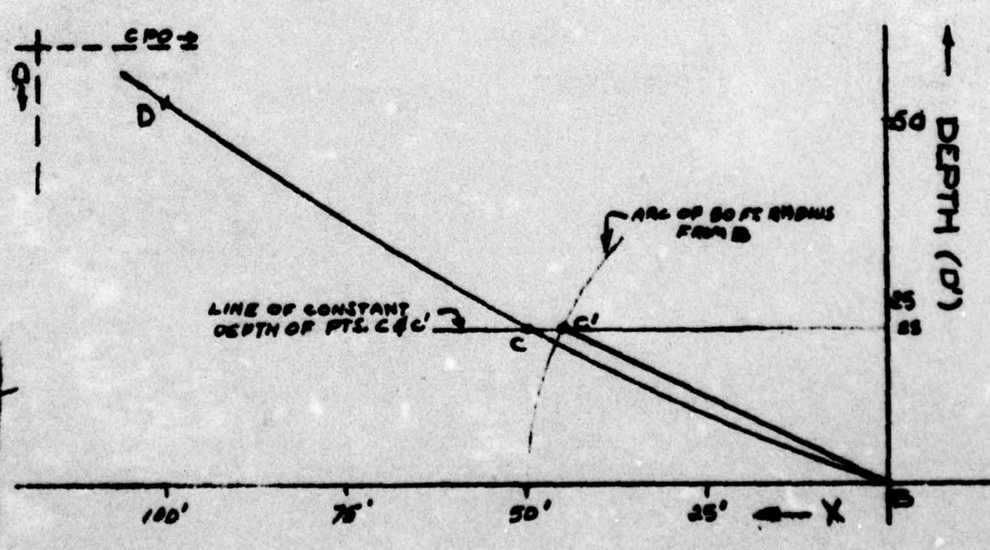
shows a typical curve of cable payed out (CPO) vs. depth (D). The shape of the towline curve can be graphically constructed from this

curve using the step-by-step procedure below.

1. Over a sufficiently small length of the towline, the towline curve can be closely approximated by a straight line.

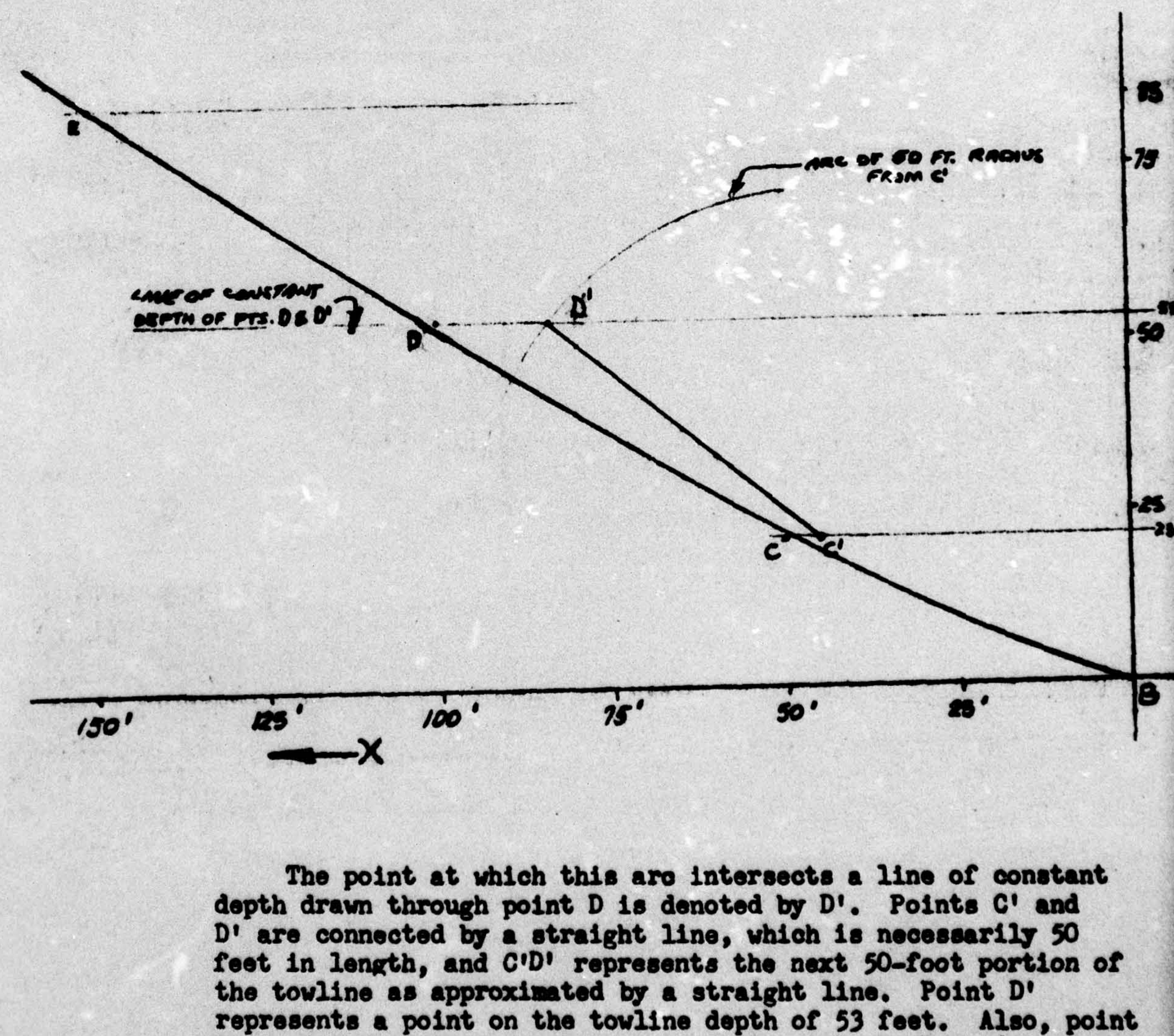
2. We now assume that, at a constant towing speed, the shape of any portion of the towline curve is not influenced in any way by any portion of the towline at a shallower depth. For example, at a given speed and for 500 feet CPO, the shape of the bottom 100 feet is not influenced in any way by the shape of the upper 400 feet.

   The above figure shows points B, C, D, E, F, G, H, I, J, K, and O spaced at equal CPO intervals of 50 feet along the horizontal CPO axis, with the corresponding depths indicated. The depth attained by the towed body is shown as a function of the length of cable payed out; for instance, the towline can be marked at equal intervals and, as each interval is payed out, a new depth is attained. Therefore BC corresponds to the first portion of the towline payed out and, as the last portion of cable is payed out (from 450 feet to 500 feet CPO), the depth of the towed body changes from 362 feet to 385 feet. Point B, representing the 500-foot CPO mark, is the point at which no more cable is payed out. For graph construction purposes, we prefer point B to be the origin of a new coordinate system, D' and X where D' drawn parallel to the D axis in the opposite direction represents depth and X represents trail, as shown below.



From point B an arc is drawn using a radius of 50 feet (scaled to the graph). The point at which this arc intersects a line of constant depth drawn through point C is denoted by C'. Points B and C' are connected by a straight line, which is necessarily 50 feet in length; and BC, in the D' and X coordinate system, is the 50-foot portion of the towline as approximated by a straight line. It is noted that C' is at a depth of 23 feet in the D' and X coordinate system.

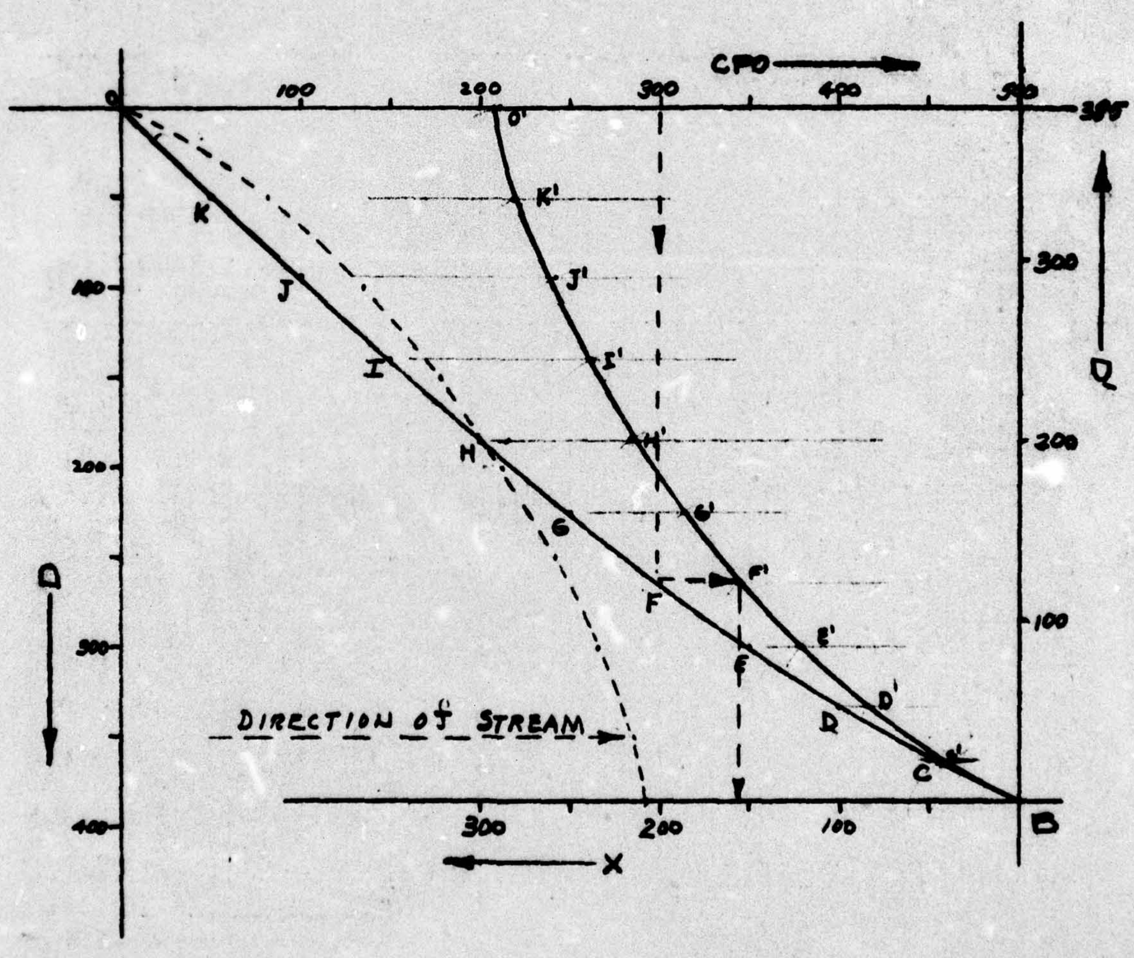
3. From Point C' an arc is drawn using a radius of 50 feet (scaled to the graph), as shown below.



The point at which this arc intersects a line of constant depth drawn through point D is denoted by D'. Points C' and D' are connected by a straight line, which is necessarily 50 feet in length, and C'D' represents the next 50-foot portion of the towline as approximated by a straight line. Point D' represents a point on the towline depth of 53 feet. Also, point D' is located 100 feet from point B along the towline (as approximated by two straight lines).

4. We proceed in the same manner used in step 3 to determine points E', F', G', H', I', J', K', and O'.

5. In place of the 50-foot line segments, a smooth curve is drawn connecting the prime points. This smooth curve (the curve connecting the prime letters) shown below represents the shape of the towline curve in the D' and X (trail) coordinate system.



If this curve is replotted with 0 as the origin, and with coordinates of depth, D↓ , and trail, X →, a non-inverted perspective of the shape of the towline curve, shown by the curved dash line is obtained. It is again noted that, for 500 feet of cable payed out, the trail is 292 feet and the depth is 385 feet.

DETERMINATION OF TRAIL

The trail for any length of CPO can be obtained using the procedure outlined below. To obtain this trail, for example, for 300 feet CPO

1. Enter the above figure along the CPO axis, in this case at 300 feet.

2. Read down to the CPO vs. D curve to obtain the depth, which is found to be 264 feet.

3. From 264 feet on the D axis read across to the towline curve and obtain X, which is found to be 156 feet.

4. Subtract 156 feet from the maximum trail to obtain the trail, 292' - 156' = 136'. Thus, for 300 feet CPO, the trail will be 136 feet.

DISCUSSION

The accuracy of the shape of the towline curve depends not only on the accuracy of the original data (CPO vs. D curve), but also on the accuracy of the person using the graphical procedure. Care should be taken to avoid the possibility of introducing a consistent error at the location of each of the prime points, which could result in a significantly large cumulative error. At the least, the compass setting should be reestablished for every arc drawn.

Point B was chosen to be at zero depth and as the origin of the D' and X coordinate system. The towline curve may also be constructed by using point 0 as the origin of a D' and X coordinate system. The towline curve thus obtained should be identical to the curve previously drawn. Any discrepancy between the two curves would result from errors introduced in performing the graphical procedure. Since the two curves are constructed independently, each will serve as a check on the other for attaining greater accuracy.

The towline curve was determined by using only depth and cable payed-out data. Other data are also available. The angle formed between the bottom of the towline (at the towed body) and a horisontal line drawn at the bottom of the towline (in the plane of the curve) can be calculated. This angle is commonly called the "towstaff angle of the towed body", and is constant for a given towing speed. From the towline curve that was graphically determined, the angle can be measured and compared with the calculation; therefore, the towline curve can be adjusted to agree with the theoretical towstaff angle of the towed body and greater accuracy in the constructed configuration can be attained.

The angle at which the towline enters the water (towline entrance angle) can also be determined experimentally, although this is usually difficult. An empirical relationship can be established between this angle and cable payed-out for a constant speed. From these empirical data and the assumption that any portion of the towline curve is not influenced by any portion of the towline that is above it, the slope at any point on the curve can be obtained. The angle formed between the tangent to any point on the graphically-constructed curve and a horison-tal line drawn through that point (in the plane of the curve) is known, and hence the slope at any point on the graphically-constructed curve is known. These slopes can be compared to the slopes obtained from measurements made at sea, as noted above or as made by the methods discussed in reference (a).

The degree of accuracy of such measurements is not very high, and it is not unreasonable to suppose that the graphical construction might yield more accurate values for the slope at any point on the towline curve.

The accuracy of the graphical construction of the towline curve can also be increased simply by performing the procedure a number of times using different values of incremental lengths and checking the consistency of the results

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per S.G.

REFERENCES

(a) Patton, K. T. "A Simple Device for the Measurement of Attitude of Submerged Objects", USL Tech. Memo. No. 933-225-65, 1 June 1965